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ECHOCARDIOGRAPHY IN THE FLIGHT PROGRAM

A Report of Ultrasound Cardiology Results
from Space Shuttle Missions

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Introduction.

Observations on American and Soviet astronauts have documented the association of changes in cardiovascular function during orthostasis with space flight. A basic understanding of the cardiovascular changes occurring in astronauts requires the determination of cardiac output and total peripheral vascular resistance as a minimum. In 1982, we selected ultrasound echocardiography as our means of acquiring this information. Ultrasound offers a quick, non-invasive and accurate means of determining stroke volume which, when combined with the blood pressure and heart rate measurements of the stand test, allows calculation of changes in peripheral vascular resistance, the body's major response to orthostatic stress.

Methods.

Pre- and post flight echocardiography during the Shuttle program began with STS-5 in 1982 (Nov., 1982) as part of DSO 402 (Fluid Loading Countermeasure). ("DSO" stands for "Detailed Supplementary Objective," an avenue for collecting operationally-important medical data on Space Shuttle crewmembers.) It was performed on a sporadic basis on volunteer crewmembers through 1986. Data from the first several flights was determined from two-dimensional (2D) echocardiographic images acquired with an instrument originally designed for obstetric use. In 1983, we upgraded to the ATL 4000 S/LC, which permitted 2D-guided M-mode imaging. Two of these units were acquired specifically for conversion into "flight units" (one primary unit and one backup unit) allowing data collection by trained crewmembers during Shuttle flights. The prime flight unit has flown on two Shuttle missions to date: STS 51-D (Apr., 1985) and STS-32 (Jan., 1990). Up to three more flights may be accomplished by this unit before it is retired.

Starting with STS-26 (Sept., 1988), several DSOs using echocardiography have allowed us to collect information on changes in cardiovascular function associated with flight duration (DSO 466), in-flight aerobic exercise (DSO 476), new fluid loading prescriptions (DSO 479), the use of LBNP as a countermeasure (DSO 478), and for correlation with heart rate and blood pressure immediately after landing (DSO 603). Beginning with STS-28 (Aug., 1989), we have been using a Biosound Genesis II echocardiograph with Doppler capability. This allows us to determine cardiac dimensions in conformance with our pre-existing data base and also to determine aortic flow by Doppler techniques

without the geometrical assumptions required by calculations based on M-mode measurements.

Results.

From 1982 through 1989, 54 crewmembers on 16 Shuttle missions volunteered to be subjects for pre- and post flight echocardiography. Typically, the ultrasound examination is performed during the operational Stand Test, a routine assessment of orthostatic function performed on all Shuttle crewmembers before launch (about ten days before flight), shortly after landing, and several days later. Continuous echocardiographic measurements were made while the crewmember was supine for five minutes, and then when the crewmember was standing upright for five minutes. The electrocardiogram was recorded continuously, and blood pressure was determined once per minute. The variables analyzed were: heart rate (HR), systolic and diastolic pressures (SBP and DBP), left ventricular end-diastolic and end-systolic dimensions, left ventricular wall thicknesses, right ventricular end-diastolic dimensions, left atrial and aortic dimensions, velocity of circumferential fiber shortening (VCF, and index of contractility), and (using Doppler) left ventricular inflow and outflow velocities. Hemodynamic parameters derived from these measurements included: mean and pulse arterial blood pressures (MAP and PP), left ventricular end-diastolic, end-systolic and stroke volume indexes (LVEDVI, LVESVI and LVSI), ejection fraction (EF), cardiac index (CI) and total peripheral resistance index (TPRI). The use of hemodynamic indexes normalizes for differences in body surface area between crewmembers. All crewmembers used the operational fluid loading protocol shortly before landing.

Briefly, the pre-Challenger data (collected only during the supine portion of the stand test) showed that left ventricular dimensions were reduced by an average of 25% after flights of 5-8 days duration; as a result, the stroke volume is similarly reduced.

Subsequently, DSO 466 allowed measurements to be made with the crewmember resting supine (actually left-lateral decubitus) and then while standing upright, during the operational stand test. Supine and standing HR were increased by 23% and 35% ($p < 0.0001$) on landing day compared to preflight. The HR response to orthostasis was also increased ($p < 0.0001$) on landing day. Supine DBP increased slightly, and supine and standing PP decreased slightly on landing day. There were no significant differences in supine or standing SBP or MAP on landing day compared to preflight. LVEDVI and LVSI were significantly decreased by 11.4% and 16.6% on landing day compared to preflight. TPRI was significantly greater in the standing position than in the supine position on all days except landing day.

In-flight measurements made on STS 51-D and STS-32 documented the decrease in left ventricular dimensions and increase in arterial pressure over the first 4-5 days in flight. Typically, late in-

flight measurements reproduced landing day measurements.

Discussion.

Cardiovascular physiological changes associated with short Space Shuttle flights include decreases in left ventricular end-diastolic volume and stroke volume indexes compensated for by increased heart rate to maintain cardiac output. Decreased LVEDVI follows the reduction in plasma volume known to occur in weightlessness.

Comparisons with echocardiographic data from the last Skylab crew and from Soviet Salyut crewmembers showed that the decrease in cardiac dimensions (and presumably function) occurs rapidly in-flight and changes only minimally after the first week in weightlessness.

These results revealed the nearly complete absence of a peripheral vascular resistance response to orthostasis on landing day after as little as 4-5 days in weightlessness. This suggests strongly that even crewmembers who are not syncopal are relying largely on their physiological reserve mechanisms (such as increased heart rate) to remain standing. If they were confronted with an emergency requiring increase performance, a successful outcome would be in doubt.

